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The effect of amplifier component maintenance on laser system availability and operating costs for the U.S. National Ignition Facility and the French Laser Megajoule

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Abstract

The amplifiers for the proposed U.S. National Ignition Facility (NIF) and the French Laser Megajoule (LMJ) will be multipassed, to reduce costs. While multipassing has the advantage of reducing front-end energy requirements, a disadvanatage is increased sensitivity of laser performance to variations in amplifier gain, gain uniformity, and pump-induced distortion. Since amplifier performance depends on the optical quality and performance of the internal amplifier components, including the flashlamps, reflectors, blastshields, and laser slabs, these components must be reliable or be easily replaced in order for the NIF and LMJ lasers to meet their performance requirements and be available for experiments a large fraction of the time. The flashlamps will be especially important in this regard, as the NIF and LMJ systems will use 8640 and 10,800 flashlamps, respectively, and flashlamp replacement has been the most common maintenance activity for previous fusion-laser systems such as Nova and Phebus.

For most optical components, reliability can be ensured by performing rigorous inspections for defects and flaws before components are installed. Experience with flashlamps on Nova and Phebus, however, shows that current inspection techniques and acceptance tests are unable to detect all flashlamp flaws that later cause premature failures. Therefore, to ensure reliability of the flashlamps, it is necessary to perform lifetime tests to qualify vendors, their flashlamp designs, and their assembly and inspection processes. Confidence levels in the flashlamp failures rates will depend on the numbers of flashlamps tested and the number of flashlamps failures in these qualification tests.

Ease of assembly and maintenance is achieved in the NIF and LMJ amplifier designs by using component cassettes that are installed and removed from the bottom with special

carts. Flashlamps cassettes hold six or eight flashlamps, while slab cassettes hold four slabs that are stacked one above the other. With this bottom-access, cart-based approach, removal and replacement of cassettes will take less than one hour, much less than the anticipated time between shots. Assuming that the flashlamp and slab replacement rates are the same as for Nova, flashlamp and slab maintenance will affect system availability only rarely, when a relatively large number of random failures occur within a short period of time. The effect of amplifier maintenance on system availability can be reduced, however, by increasing the number of spare cassettes and components, by increasing the size of the maintenance teams, and by increasing the number of maintenance carts and refurbishment stations.

This paper describes amplifier ray-trace modeling and laser propagation modeling that shows that the unlikely failure of several flashlamps on the same shot will be required for flashlamp failures to significantly affect laser performance. In addition, this paper presents statistical analyses used to design the flashlamp vendor qualification tests and to determine the number of component spares and maintenance resources necessary to ensure that the amplifiers have minimal impact on overall system availability. These statistical analyses show that qualification tests on groups of approximately 200 flashlamps will be sufficient to determine, with a high confidence level, whether flashlamp designs meet the NIF and LMJ reliability requirements. In addition, the statistical analyses show that maintenance some 10-12 spare flashlamp and slab cassettes will be sufficient to ensure that the NIF and LMJ systems do not run out of spares.

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